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REISSUE PATENT APPLICATION TRANSMITTAL

Address to:

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Washington, DC 20231

Attorney Docket No.	D9353-RE
First Named Inventor	Mark S. Zediker
Original Patent Number	5,715,270
Original Patent Issue Date (Month/Day/Year)	February 3, 1998
Express Mail Label No.	

APPLICATION FOR REISSUE OF: *(check applicable box)* [X] *Utility Patent* [ ] *Design Patent* [ ] *Plant Patent*

APPLICATION ELEMENTS

1. [XX] * Fee Transmittal Form *(PTO/SB/56)* *(Submit an original, and a duplicate for fee processing)*
2. [XX] Specification and Claims (*amended, if appropriate*)
3. [XX] Drawing(s) *(proposed amendments, if appropriate)*
4. [ ] Reissue Oath / Declaration (original or copy) *(37 C.F.R. § 1.175)(PTO/SB/51 or 52)*
5. Original U.S. Patent
   - [ ] Offer to Surrender Original Patent *(37 C.F.R. § 1.178) (PTO/SB/53 or PTO/SB/54)*
   - *or*
   - [ ] Ribboned Original Patent Grant
   - [ ] Affidavit / Declaration of Loss *(PTO/SB/55)*
6. Original U.S. Patent currently assigned? [XX] Yes [ ] No
   (If Yes, check applicable box(es))
   - [ ] Written Consent of all Assignees *(PTO/SB/53 or 54)*
   - [ ] 37 C.F.R. § 3.73(b) Statement [ ] Power of Attorney

ACCOMPANYING APPLICATION PARTS

7. [ ] Foreign Priority Claim *(35 U.S.C. 119)* *(if applicable)*
8. [ ] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
9. [ ] English Translation of Reissue Oath/Declaration *(if applicable)*
10. [ ] * Small Entity Statement(s) *(PTO/SB/09-12)* [ ] Statement filed in prior application, Status still proper and desired
11. [ ] Preliminary Amendment
12. [XX] Return Receipt Postcard *(MPEP 503)* *(Should be specifically itemized)*
13. [XX] Other: Request to Transfer Drawings

NOTE FOR ITEMS 1 & 10: IN ORDER TO BE ENTITLED TO PAY SMALL ENTITY FEES, A SMALL ENTITY STATEMENT IS REQUIRED (37 C.F.R. § 1.27), EXCEPT IF ONE FILED IN A PRIOR APPLICATION IS RELIED UPON (37 C.F.R. § 1.28).

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REISSUE APPLICATION FEE TRANSMITTAL FORM

Docket Number (Optional)
D9353-RE

Claims as Filed - Part 1

Claims in Patent	For	Number Filed in Reissue Application	(3) Number Extra		Small Entity Rate	Small Entity Fee		Other than a Small Entity Rate	Other than a Small Entity Fee
(A) 24	Total Claims (37 CFR 1.16(j))	(B) 41	**** 17	=	x $____ =		or	x $ 18 =	306
(C) 4	Independent Claims (37 CFR 1.16(i))	(D) 14	* 10	=	x $____ =			x $ 78 =	780
			Basic Fee (37 CFR 1.16(h))			$___			$ 690
			Total Filing Fee			$		OR	$ 1,776

Claims as Amended - Part 2

	(1) Claims Remaining After Amendment		(2) Highest Number Previously Paid For	(3) Extra Claims Present	Small Entity Rate	Small Entity Fee		Other than a Small Entity Rate	Other than a Small Entity Fee
Total Claims (37 CFR 1.16(j))	***	MINUS	**	* =	x $____ =		or	x $____ =	
Independent Claims (37 CFR 1 16(i))	***	MINUS	*****	=	x $____ =			x $____ =	
			Total Additional Fee			$		OR	$

* If the entry in (D) is less than the entry in (C), Write "0" in column 3.
** If the "Highest Number of Total Claims Previously Paid For" is less than 20, Write "20" in this space.
*** After any cancelation of claims
**** If "A" is greater than 20, use (B -A); if "A" is 20 or less, use (B - 20).
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HIGH EFFICIENCY, HIGH POWER DIRECT DIODE LASER SYSTEMS AND METHODS THEREFOR

BACKGROUND OF THE INVENTION

The present invention relates generally to diode laser array systems. More specifically, the present invention relates to high efficiency, high power direct diode laser systems.

In numerous applications such as laser tracking, laser guidance and laser imaging, it is desirable to produce a high power coherent laser output. Moreover, high power coherent laser systems find applications in such diverse fields as offensive and defensive weapon systems, e.g., non-visible light illuminators for special operation forces and protective laser grids, as well as material processing, e.g., welding, cutting, heat treating and ablating, and medicine, e.g., surgical and diagnostic aides.

In the earliest laser systems, single semiconductor lasers were utilized to provide a coherent source of laser output. These single semiconductor lasers were limited in the amount of power which they could provide due to their structural limitations and limited efficiency. More recently, arrays of semiconductor lasers have also been utilized in which adjacent emitters of the array of semiconductor lasers spaced upon the same substrate are coupled together. One such laser array system was disclosed in commonly assigned U.S. Pat. No. 5,212,707 to Heidel et al., which is incorporated herein by reference for all purposes.

FIG. 1 illustrates a one-dimensional semiconductor laser array 10 according to U.S. Pat. No. 5,212,707, which is mounted on a heatsink 12. The semiconductor laser array 10 has an associated lens assembly 22, 24 for collimating the laser array's output, which is positioned adjacent to the emitting facet of the semiconductor laser array 10. Lens assembly 22, 24 is attached to the ears 25 of the heatsink 12. The emitters 20 of the array 10 are supplied with power from an external power supply via wires 18, a standoff pad 16 and a power lead 14. In an exemplary case, the semiconductor laser array 10 shown in FIG. 1, includes ten individual emitters 20; and number of emitters 20 may be employed as determined by the requirements of the particular application.

Once the semiconductor laser array 10 has been fabricated, mounted and powered, the output of the semiconductor laser array's emitters 20 must be collimated in order to obtain the desired collimated output. The lens assembly, as shown in FIG. 1, which is designed to collimate the output of the semiconductor laser array 10, includes a first refractive lens 22, typically of a biconvex design, and a second binary optical element 24, which is essentially a diffractive lens. The refractive biconvex lens 22 collimates the fast axis of each emitter 20 while the binary optical element 24 serves to collimate the slow axis of each emitter 20 and correct all spherical aberrations including those introduced by the collimation performed by the refractive lens 22.

The binary optical element 24 includes a substrate on which a binary optical diffraction pattern 26 is etched. Generally, the materials of the refractive lens 22 and the binary optical element 24 have substantially equivalent refractive indices such that minimal refraction occurs at the interface between the refractive lens 22 and the binary optical element 24. The binary optical element 24 has a back surface 27 positioned adjacent to the front surface 28 of the refractive lens 24 and a front surface 28 on which the binary optic diffraction pattern 26 is etched. Since the binary optical

diffraction pattern **26** is produced in accordance with typical binary optic technology, as well known to those of ordinary skill in the art (See U.S. Pat. No. 4,846,552.), further discussion of this technology will not be provided.

The binary optic diffraction pattern **26** is typically an eight phase level structure (although a two, four, or sixteen-phase level structure could also be utilized) which corrects for optical path differences inherent in the divergent output light of an emitter of a semiconductor laser array. Thus, the rays of light which exit the binary optic element **24** will have all travelled equal optical pathlengths, defined as a physical pathlength multiplied by the index of refraction of the material through which the light rays travelled which are equal or varied from that equal optical pathlength by only an integer multiple of the wavelength of the light being emitted. An eight level binary optic diffractive pattern **26** is shown schematically in FIG. **1**.

A two-dimensional semiconductor laser array can be fabricated from a plurality of the one-dimensional semiconductor laser arrays **10** shown in FIG. **1**. The one-dimensional semiconductor laser arrays **10** are stacked as shown in FIG. **2** within a heatsink which serves as a holding or clamping fixture **70**. The clamping fixture **70** is designed such that the one-dimensional semiconductor laser arrays **10** may be stacked on top of one another so that the outputs of each one-dimensional semiconductor laser array are substantially parallel to the outputs of the other semiconductor laser arrays.

Once the one-dimensional semiconductor laser arrays **10** have been mounted within the clamping fixture **70**, the collimating lenses are aligned and attached. The fabrication of the collimating lenses is done in a manner identical to that previously discussed such that the refractive lens **22** is cemented to the binary optical element **24** which has been designed to collimate the laser output of each emitter **20**. The alignment and attachment of the collimating lenses is accomplished in a sequential fashion for optimum efficiency. The collimating lenses **80*a*** associated with the first one-dimensional semiconductor laser array **10*a*** are positioned as previously described such that the optical axes of each emitter **20** of the semiconductor laser array **10** are substantially aligned with the center of the collimating lens assembly **80*a***.

The second collimating lens assembly **80*b*** is then placed in front of a second one-dimensional semiconductor laser array **10*b*** and is held in position by means of a vacuum chuck **76** connected by a vacuum line to a vacuum source, as shown in FIG. **3**. The two-dimensional semiconductor laser array **10** is then supplied power such that the emitters **20** produce a light output. A transform lens **72** is positioned within the path of the light emitted from the first and second one-dimensional semiconductor laser arrays. The transform lens **72** may be a plano-convex or a biconvex lens, as shown in FIG. **3**, such that a simulated far field will appear at the focal plane of the transform lens **72** when the input light to the transform lens **72** is collimated. To determine the simulated far field, when all beams of light overlap at the focal plane of the transform lens **72**, a line scan detector **74** is positioned at the focal plane. The output of the line scan detector is monitored to determine if proper collimation has been achieved. The position of the second collimating lens assembly **80*b*** is varied until proper collimation is observed at the focal plane of the transform lens. Once proper collimation is observed, the position of the second collimating lens assembly **80*b*** is preserved by fixing the lens assembly in position in the ears **25** of the clamping fixture **70**. An identical alignment procedure is done for each lens

assembly and its corresponding one-dimensional semiconductor laser array **10**, until the lens assembly for each semiconductor laser array **10** has been properly aligned such that the light is collimated and focused at the simulated far field.

The two-dimensional laser array when properly supplied with power produces a single collimated spot of laser output in the far field. By utilizing a plurality of one-dimensional semiconductor laser arrays **10** whose outputs may be combined, the output power of the two-dimensional semiconductor laser array may be quite high. For example, 25 watts of continuous wave laser energy was produced by a two-dimensional semiconductor laser array consisting of twelve one-dimensional semiconductor laser arrays with each one-dimensional semiconductor laser array having twenty one emitters. Additionally, the overall efficiency of the laser array from electrical input to power in the central lobe was approximately 26%.

U.S. Pat. No. 5,299,222 discloses an alternative approach to producing a high power laser diode system that collects and concentrates laser output from a stack of diode laser bars in a form that is useful and flexible for pumping a laser, e.g., a solid state laser. As shown schematically in FIG. **4**, the light beam output of stacked diode laser bars is coupled into a plurality of optical fibers. The output light beams from the fibers may be used to pump a laser resonator. The fibers can be grouped at various end points of a solid-state laser cavity for efficient end-pumping. In FIG. **4**, a light beam **11** is emitted by a plurality of diode laser bars in a diode laser bar stack **13**, and light from a selected group of the bars is collected by one of a plurality of cylindrical lenses **15** positioned adjacent to but spaced apart from each diode bar in the stack **13**. Each diode laser bar may have an aspect ratio (length-to-width) as high as 10,000:1, or even higher, and the cylindrical lenses **15** are interposed to reduce the beam divergence angle in a first direction, relative to the beam divergence angle in a second, perpendicular direction, so that the resulting beam divergence angle in each of the two directions is roughly the same.

Two or more turning mirrors **17A**, **17B**, **17C** and **17D** separate mutually exclusive portions of the light beam **11** into non-overlapping light beam components **19A**, **19B**, **19C** and **19D**, respectively, and at least one pump light beam component, such as **19E**, is optionally defined by a portion of the light beam **11** that does not encounter a turning mirror. Each light beam component **19A**, **19B**, **19C**, **19D** and **19E** is then focussed by suitable focusing optics **21A**, **21B**, **21C**, **21D** and **21E**, respectively, into a corresponding multimode optical fiber **23A**, **23B**, **23C**, **23D** and **23E**, respectively, with the diameters of the fibers being chosen to fully capture the optical beam intended for that fiber. Preferably, the sine of the convergence angle as a light beam arrives at a light-receiving end of a fiber is less than the numerical aperture NA of that fiber. In one embodiment, each optical fiber has a diameter of about 500 μm, but this fiber diameter may be as large as a few mm. Each of the focusing optics **21*j*** (j=A, B, C, D or E) may be a lens with a short focal length, such as f=6.35 mm, and is intended to cause the resulting beam to converge to an entrance diameter, measured at the entrance of the corresponding fiber **23*j***, that is about 25 percent of the diameter of the portion of the pump light beam **11** that arrives at the focusing optics **21*j***.

The numerical aperture NA of the multimode fiber **23*j*** lies in the range 0.15–0.3 but may be as high as 0.6. Each optical fiber **23*j*** delivers the component pump light beam propagating therein to a selected position and with a selected angular orientation relative to the laser cavity to be pumped

by this collection of component pump light beams. Each optical fiber **23*j*** is provided with an anti-reflective coating at the diode laser wavelength P, and the coating is either applied directly to the fiber end or to a separate glass window that is bonded to the light-receiving end of that fiber. The core material of the fiber **23*j*** may be glass, and the cladding material of the fiber may be glass or plastic, with a smaller refractive index than the core refractive index, which determines by the numerical aperture of the fiber in a manner well known in the art.

It will be appreciated that expansion of the systems discussed immediately above would require both a large amount of real estate and complex optic assemblies to couple the outputs of a plurality of the disclosed output modules to a single spot. For example, the presence of lens **72** in FIG. **3** suggests the need for a focusing lens associated with each module; FIG. **4** suggests that a plurality of lenses **21** are needed to efficiently couple the output of a single diode laser array. It would be desirable for a plurality of semiconductor laser arrays to produce a single spot of high intensity laser output using a simple and robust optical subsystem. Furthermore, it would be desirable for a plurality of semiconductor laser arrays to be mounted evenly and the outputs thereof collimated in such a manner as to fill the available aperture to thereby provide a substantially constant intensity across the single spot of laser output produced.

SUMMARY OF THE INVENTION

Based on the above and foregoing, it can be appreciated that there presently exists a need in the art for a diode laser system which overcomes the above-described deficiencies.

An object according to the present invention is to provide a direct diode laser system generating a high fluence level at a workpiece.

Another object according to the present invention is to provide a direct diode laser system which generates a high power laser beam. According to one aspect of the present invention, the high power laser beam can be focused onto a single spot for interaction with a workpiece. According to another aspect of the present invention, the high power laser beam may be directed into one end of a solid state laser.

A still further object of the present invention is to provide a direct diode laser system which generates a high fluence level at a workpiece using dichroic coupling of multiple frequency collimated laser beams. Advantageously, all of the collimated laser beams can be generated using laser diode arrays.

Yet another object of the present invention is to provide a direct diode laser system which generates a high fluence level at a workpiece using both dichroic and polarization coupling of multiple frequency collimated laser beams. Advantageously, all of the collimated laser beams can be generated using laser diode arrays.

An additional object of the present invention is to provide a direct diode laser system which generates a high fluence level at a workpiece by simultaneously coupling thousands of collimated laser diode outputs into a single fiber via a single lens.

Another object of the present invention is to provide a direct diode laser system which generates a linearly scalable high power level output.

These and other objects, features and advantages of the present invention are provided by a direct diode laser system which includes N laser head assemblies (LHAs) generating N output beams, N optical fibers receiving respective ones

of the N output beams and generating N received output beams, and a torch head recollimating and focusing the N received output beams onto a single spot. According to one aspect of the invention, each of the laser head assemblies of the direct diode laser system includes M modules generating M laser beams, wherein each of the M laser beams has a corresponding single wavelength of light, M-1 dichroic filters, wherein each of the M-1 dichroic filter transmits a corresponding one wavelength of the M laser beams and reflects all other wavelengths of the M laser beams, and a fiber coupling device collecting the M laser beams to produce a respective one of the N output beams.

These and other objects, features and advantages of the present invention are provided by a direct diode laser system, including N laser head assemblies (LHAs) generating N output beams, wherein each of the N laser head assemblies includes M first modules generating M first laser beams, wherein each of the M first laser beams has a corresponding single wavelength of light, M-1 first dichroic filters defining a first optical waveguide for directing all of the M first laser beams into a first optical path, wherein each of the M-1 first dichroic filters transmits a corresponding one of the M first laser beams having a respective wavelength and reflects all other wavelengths of the M first laser beams, a fiber coupling device disposed adjacent to the first optical path for collecting the M first laser beams to produce a respective one of the N output beams, N optical fibers receiving respective N output beams and generating N received output beams, and a torch head recollimating and focusing the N received output beams on a single spot.

These and other objects, features and advantages according to the present invention are provided by a method for generating a high energy laser beam, including steps for:

(a) generating P collimated laser beams having an Mth wavelength;
(b) repeating step (a) M times so as to produce M×P collimated laser beams having M different wavelengths;
(c) coupling the M×P collimated laser beams into an optical path;
(d) coupling the M×P collimated laser beams into an ith optical fiber to thereby produce a corresponding ith output laser beam, where i=1 to N;
(e) repeating steps (a) through (d) N times to thereby generate N output laser beams;
(f) recollimating the N output laser beams to produce N recollimated laser beams; and
(g) focusing the N recollimated laser beams onto a single spot.

These and other objects, features and advantages of the invention are disclosed in or will be apparent from the following description of preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

These and various other features and aspects of the present invention will be readily understood with reference to the following detailed description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a perspective view of a one-dimensional semiconductor laser array assembly, a refractive lens, and a binary optic element;

FIG. 2 is a two-dimensional semiconductor laser array and its associated collimating optics held within a clamping fixture;

FIG. 3 is a side view of a transform lens in a two-dimensional semiconductor laser array structure illustrating the proper collimation of laser diode outputs by a collimating lens assembly;

FIG. 4 is a schematic view of an optical system used to couple the outputs of a 1 cm length diode laser stack into five separate fibers;

FIG. 5 is a high level block diagram of a high efficiency, high power direct diode laser system according to the present invention;

FIG. 6 is a more detailed block diagram of selected components of the high efficiency, high power direct diode laser system shown in FIG. 5;

FIG. 7 is a detailed schematic diagram of the optic bed of one of the assemblies illustrated in FIG. 6, which is useful in understanding one facet of system power scaling according to the present invention;

FIG. 8 is a side view of a diode laser array module which can be employed in an exemplary embodiment according to the present invention; and

FIG. 9 is an illustration of an exemplary configuration of the torch head assembly of FIG. 5.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 5 is a high level block diagram of the high efficiency, high power direct diode laser system (DLS) 1 according to alternate preferred embodiments of the present invention. As illustrated in FIG. 5, the DLS 1 includes a power supply **100** providing power to both a controller **200** and N laser head assembly (LHA) controllers generally denoted **300**. N laser head assemblies (LHAs) generally denoted **400** receive the output power of the LHA controllers **300**, respectively, and provide N optical output laser beams to a torch head **500** via N optical fibers. It should be mentioned that the torch head **500** advantageously can be augmented by a laser head **510** (See FIG. 9.), and, thus, the alternative designation in FIG. 5.

Preferably, the number N of LHA controllers **300** and LHA's **400** can be varied as required to provide a desired output power of the DLS 1. In an exemplary case, 4 LHA controllers **300A**, **300B**, **300C** and **300N** providing electrical power to 4 LHAs **400A**, **400B**, **400C** and **400N**, respectively, are included in the DLS 1. The block diagram of FIG. 5 illustrates a DLS 1, in which the optical output laser beams of 4 LHAs **400**, each producing 800 watts of power, are combined to deliver over 3200 watts of cw power to a single focusing lens. As discussed in greater detail below with respect to FIG. 9, the output of each respective LHA **400** advantageously can be fiber coupled and at the distal end of each fiber (approximately 1 mm diameter) they can be recollimated. The 4 collimated laser sources, i.e., the 4 output optical beams, preferably are collected by a single lens, which focuses the 3200 watts of total power onto a single point. It will be appreciated that this latter technique is commonly used in industrial laser systems to increase fluence on the work piece.

In an exemplary embodiment of the DLS 1 of FIG. 5, the power supply provides DC power to controller **200** and LHA controllers **300**. Preferably, controller **200** acts as a master controller with respect to the N LHA controllers **300**, which act as slave controllers. It should also be mentioned that each of the N LHA controllers **300** controls and varies the output optical beam of the respective LHA **400**, as discussed in greater detail below.

FIG. 6 is an intermediate level block diagram showing additional details of the LHA **400** and torch head **500** components illustrated in FIG. 5. Advantageously, each of the N LHAs **400** includes M diode laser modules **410**, of

which the output beams of M/2 modules and combined with the output beams of the other M/2 modules 410 using polarization combiner 450. The combined output beam of each of the N polarization combiners 450 is provided to torch head 500 via fiber coupling optics 460 and a respective optical fiber 470.

Referring now to FIG. 7, a detailed description of an exemplary embodiment of LHA 400 will now be presented. Preferably, M diode laser modules 410 are disposed on a support plate or optic bed 430 in groups of M/2 modules 410, the left and right groups of modules 410 being disposed on opposite sides of a polarization combiner (polarizer) 450. The output beams of the left set of M/2 modules 410 are combined using (M/2)-1 dichroic filters 420 and directed to the reflecting surface of polarizer 450. The output beams of the right set of M/2 modules 410 are combined using an *additional (M/2)-1 dichroic filters 420 and directed to the* transmitting surface of polarizer 450 via waveplate 440. Polarizer 450 combines the left and right sets of M/2 laser beams produced by the left and right M/2 module sets in a manner well known to those of ordinary skill in the art.

The output beams of the polarizer 450 are transmitted to the optical fiber 470 via fiber coupling optics 460. Advantageously, fiber coupling optics may include a relay mirror 462, a transform lens 464 and a fiber coupler 466, arranged in that order along the optical path of the LHA 400. Preferably, polarizer 450 and the relay mirror 463 provide 2 axis adjustment while the transform lens 464 provides 5 axis adjustment. In the exemplary case illustrated in FIG. 7, waveplate 440 produces polarization rotation of the output beams of the right group of M/2 modules.

Advantageously, each of the left and right sets of modules 410 produce output beams each having a different single wavelength, the wavelength separation between the output beams being only dependent on the quality of the dichroic filters used in the DLS 1. (M/2)-1 of the modules 410 are disposed behind a respective optical bandpass filter 420 which transmits only the output beam from that module and reflects all other wavelengths of light. Since the module is mechanically independent of the associated dichroic filter 420, the dichroic filters 420 can be aligned separately from the modules 410. After all of the modules 410 are combined in wavelength, then the broadband polarizer 450 is used to combine the output beams from the opposing groups of M/2 modules 410 into a single high brightness beam.

As discussed immediately above and as shown in FIG. 7, twelve 100 watt collimated diode laser modules 410, six each in left and right groups, are combined for launching into a single optical fiber. It should be noted that each module 410 in one of the left and right groups of modules 410 produces laser light at a single selected wavelength. Preferably, the selected wavelength corresponds to the band-pass wavelength of one of the dichroic filters 420. The selected wavelength preferably is within the range of approximately 450 nm to 2.5 microns, and the selected wavelengths preferably all fall within the 760–1050 nm range, with the range of 800–980 nm being most preferable for the exemplary case illustrated in FIG. 7. It should also be mentioned that the minimum differential wavelength for any *two of the modules 410 is approximately 10 nm, which* corresponds to the minimum band pass of the dichroic filters 420 available using present technology. Thus, the number M of modules 410 in each LHA 400 is 20 for each 100 nm in bandwidth of the output of torch head 500 when both dichroic filters 420 and polarizer 450 are employed and 10 for each 100 nm in bandwidth when only dichroic filters 420 are employed. However, the number M of modules can be

increased as the passband of each of the dichroic filters **420** decreases. It should be mentioned that dichroic filters **420** advantageously can be low, high or band pass filters.

It will also be appreciated that the wavelengths produced by the modules **410** advantageously can be selected to facilitate use of the DLS 1. For example, a single one of the modules **410** can produce a wavelength in the visible portion of the spectrum so as to provide a guide beam for reasons of safety.

Each of the modules **410** advantageously can be constructed as shown in FIG. **8**, wherein a plurality of laser diode arrays **414** are supported by a heatsink **412** within a case **418**. Preferably, 3 or more tilt correcting mirrors **416** are used to combine the outputs of the laser diode arrays **414** into a highly collimated output beam. Preferably, each module **410** advantageously includes P laser diodes. It will be appreciated that the only significant limit on the number P is the number of laser diodes which can be effectively cooled.

It should be noted that the modules **410**, while similar to those disclosed in U.S. Pat. No. 5,212,707 in some respects, are significantly different in a number of other respects. The modules described in U.S. Pat. No. 5,212,707 were actually fabricated and tested as part of a 100 watt fiber coupled system that was sold by the assignee in 1993. While these modules produced highly collimated laser diode arrays, there have since been several new developments in technology that have enabled the modules **410** to be enhanced vis-a-vis those disclosed in U.S. Pat. No. 5,212,707. For example, the basic emitters used in the patent were index guided devices, i.e., rib lasers. In contrast, the modules **410** according to the present invention advantageously can be gain guided structures, in particular, 20 micron wide oxide defined stripes. While the laser diode array **414** does not produce the same divergence as the index guided structures described in U.S. Pat. No. 5,212,707, they do produce significantly higher output power levels. Moreover, the additional improvements that have developed since the '707 patent was issued include:

(a) The use of high power index guided devices, such those found in Model No. SDL 5410 by Spectra Diode Labs, Inc.;

(b) The use of a tapered oscillator design which is, in general, an oxide defined stripe but with a diverging wavefront; and

(c) Improved binary optics, whereby it is no longer necessary to use a refractive element to share the power and collimate the light from the emitters. It will be appreciated that this latter improvement alone increases the effective fluence produced by each of the laser diode arrays **414**.

Implementing all of these improvements collectively can dramatically increase the brightness of the module **410** over the original design used in the modules described in U.S. Pat. No. 5,212,707.

It should also be noted that the module **410** illustrated in FIG. **8** includes pointing mirrors **416** in the basic module structure. These pointing mirrors are used to direct the output beam exiting the module **410** through the optical path illustrated in FIG. **7** and into the optical fiber **470**. Advantageously, the pointing mirrors **416** provide the fine adjustments required to achieve a high coupling efficiency to the optical fiber **470**. It should also be noted that the first commercial systems according to U.S. Pat. No. 5,212,707 provided 100 watt output power by polarization coupling two of the laser diode arrays shown in FIGS. **2** and **3**. This approach to intramodule coupling was discarded in favor of

the module configuration shown in FIG. 8, which advantageously decreases the overall size of module 410 while increasing fluence at the workpiece.

Another improvement to the basic design of the modules 410 is the use of stackable microchannnel coolers to increase the packing density of the laser diodes and consequently reduce the overall size of the system. Advantageously, cooling systems such as that disclosed in U.S. Pat. No. 5,495,490, which patent is incorporated by reference for all purposes, can be used.

Referring to FIG. 9, a preferred embodiment of the torch head 500 includes N collimating lenses 504, which receive output beams from optical fibers 470 via N fiber outputs 502 and which, in conjunction with transform lens 506, focus the N output beams onto a single spot. It will be appreciated that the output of M×N×P laser diodes are focused onto a single spot by torch head 500. Alternatively, it will be appreciated that the output of the LHAs 400 can be combined to end pump a solid state laser rod 510 using an identical or similar structure as that shown in FIG. 9. It should be mentioned that the number of collimating lenses in torch head 500 is N, the number of LHAs 400. It should also be mentioned that the laser rod 510 advantageously can be replaced by either a rare-earth doped optical fiber or a dye laser, i.e., any laser amplifying medium can be serially coupled to head 500.

As discussed above, the DLS 1 shown in FIG. 5 is for an exemplary case in which the output beams of four LHAs 400 are combined to deliver over 3200 watts of cw power to a single focusing lens 506. It should be noted that the output beam of each LHA 400 is produced by dichroic and polarization combining of the outputs of twelve modules 410.

It should be recognized that the output power of the DLS 1 can be varied in a number of ways. First, the number N of LHAs 400 can be varied. For example, doubling the number N of LHAs 400 would double the combined power of the output beams. Alternatively, the number M of modules 410 and corresponding dichroic filters could be varied to vary the output power level. In an exemplary case, reducing the number M from 12 to 6 would halve the output power of that particular LHA 400. Finally, it should be noted that the output power of the DLS 1 can advantageously be varied by controlling either the number M×N of system modules 410 energized or by controlling the excitation power level to some portion of the M×N modules 410. Although the output power can be adjusted by uniformly adjusting the excitation current to the M×N modules 410, it will be appreciated that control at the upper and lower limits of system power may be difficult. For that reason, selected portions of the M×N modules may be controlled while the remainder of the M×N modules 410 may be either on or off, depending on the desired system output power. It should also be recognized that the output power of the selected M×N modules 410 may be varied in accordance with excitation current in a cw operating mode or may be varied in accordance with duty cycle in a pulsed operating mode.

As discussed above, the output of each respective module is fiber coupled to an optical fiber 470. It should be noted that the transform lens 464 focuses and couples the entire output beam of LHA 400 into fiber 470. Preferably, the sine of the convergence angle as the light beam arrives at the light-receiving end of the fiber 470 is less than the numerical aperture NA of that fiber. Advantageously, the NA of the fiber 470 is less than 0.47. Preferably, the NA of the fiber 470 is ≦0.19 and, most preferably, the NA of the optical power is ≦0.16.

Preferably, the fiber coupling lens 464 is a lens designed specifically for focusing the collection of beams from the

wide wavelength band system of LHA **400** into the optical fiber **470**. The number of modules **410** shown in the exemplary case illustrated in FIG. **7** was chosen to meet the optical power budget required at the fiber output and is entirely dependent on the quality of the optics used. As discussed previously, the only criteria is that the system produce 800 watts out of the fiber and be contained within a 0.16 NA.

Those of ordinary skill in the art will appreciate that the commercial applications range from surgery, to cutting, welding, and heat treating metals. In addition, this DLS **1** will be ideal for paint stripping, curing, cutting and drilling composite materials. Military applications range from an off-gimbal illumination system to a delay denial system for nuclear storage areas.

Another key application for this technology will be as an optical pump for solid state lasers, as discussed above, based on rare earth elements. This configuration facilitates excellent end pumping of a solid state laser rod, rare-earth doped fiber or dye laser. Moreover, this configuration has proven to be the most efficient means yet devised for converting incoherent laser diode pump light into a high quality, high brightness beam.

Although a presently preferred embodiment of the present invention has been described in detail hereinabove, it should be clearly understood that many variations and/or modifications of the basic inventive concepts herein taught, which may appear to those skilled in the pertinent art, will still fall within the spirit and scope of the present invention, as defined in the appended claims.

What is claimed is:

1. A diode laser system, comprising:

N laser head assemblies (LHAs) generating N output beams, wherein each of said N LHAs includes:

M modules generating M laser beams, wherein each of said M laser beams has a different single wavelength;

M-2 dichroic filters, wherein each of said M-2 dichroic filters transmits a corresponding one of said M laser beams and reflects all other of said M laser beams;

a fiber coupling device collecting said M laser beams to produce a respective one of said N output beams;

N optical fibers receiving respective ones of said N output beams and generating N received output beams; and

an optical assembly recollimating and focusing said N received output beams on a single spot,

where N and M are both integers ≧2.

2. The diode laser system as set forth in claim **1**, further comprising N LHA controllers controlling the output power produced by respective ones of said N LHAs.

3. The diode laser system as set forth in claim **1**, further comprising a LHA controller controlling the output power produced by all of said N LHAs.

4. The diode laser system, as set forth in claim **1**, wherein said optical assembly comprises:

N collimating lenses for recollimating respective ones of said N output beams; and

a single transform lens focusing said recollimated N output beams onto said single spot.

5. The diode laser system as set forth in claim **4**, wherein said single spot corresponds to one end of a solid state laser rod.

6. The diode laser system as set forth in claim **4**, wherein said single spot corresponds to one end of a rare earth doped optical fiber.

7. The diode laser system as set forth in claim **1**, wherein each of said LHAs comprises:

M/2 first modules generating M/2 first laser beams, wherein each of said M/2 first laser beams has a corresponding single wavelength;

(M/2)-1 dichroic first filters, wherein each of said (M/2)-1 dichroic first filters transmits a corresponding one of said M/2 first laser beams and reflects all other of said M/2 first laser beams;

M/2 second modules generating M/2 second laser beams, wherein each of said M/2 second laser beams has a corresponding single wavelength;

(M/2)-1 dichroic second filters, wherein each of said (M/2)-1 dichroic second filters transmits a corresponding one of said M/2 second laser beams and reflects all other of said M/2 second laser beams;

a polarizer coupling first and second M/2 laser beams to thereby produce M polarization coupled laser beams; and

a fiber coupling device collecting said M polarization coupled laser beams to produce a respective one of said N output beams.

8. The diode laser system as set forth in claim 1, wherein said each of said M-2 dichroic filters band pass filters said corresponding one of said M laser beams and reflects all other of said M laser beams.

9. A diode laser system, comprising:

N laser head assemblies (LHAs) generating N output beams, wherein each of said N LHAs includes:

M first modules generating M first laser beams, wherein each of said M first laser beams has a different single wavelength;

M-1 first dichroic filters defining a first optical waveguide for directing all of said M first laser beams into a first optical path, wherein each of said M-1 first dichroic filters transmits a corresponding one of said M first laser beams and reflects all other said M first laser beams;

a fiber coupling device disposed adjacent to said first optical path collecting said M first laser beams to produce a respective one of said N output beams;

N optical fibers receiving respective ones of said N output beams and generating N received output beams; and

an optical assembly recollimating and focusing the N received output beams onto a single spot,

where N and M are both integers ≧2.

10. The diode laser system as set forth in claim 9, wherein said optical assembly comprises:

N collimating lenses for recollimating said N output beams; and

a single transform lens for focusing said recollimated N output beams onto said single spot.

11. The diode laser system as set forth in claim 10, wherein said single spot corresponds to one end of a laser amplifying medium.

12. The diode laser system as set forth in claim 9, wherein each of said LHAs further comprises:

M second modules generating M second laser beams, wherein each of said M second laser beams has a different single wavelength;

M-1 second dichroic filters defining a second optical waveguide for directing all of said M second laser beams into a second optical path, wherein each of said M-1 second dichroic filters transmits a corresponding one of said M second laser beams and reflects all other said M second laser beams;

a rotating element for rotating the polarizations of said M second laser beams; and

a polarizer disposed at the intersection of said first and second optical paths coupling said M first and M second laser beams into the second optical path to thereby produce 2M polarization coupled laser beams;

wherein said fiber coupling device collects said 2M polarization coupled laser beams to produce a respective one of said N output beams.

13. The diode laser system as set forth in claim 9, wherein said fiber coupling device comprises a transform lens receiving and coupling said M first laser beams to one of said N optical fibers to thereby produce a respective one of said N output beams.

14. A diode laser system, comprising:

means for generating N laser beams, wherein each of said N laser beams includes multiple wavelengths of light and wherein said generating means comprises:

M first means for generating M first laser beams, wherein each of said M first laser beams has a different single wavelength;

M-1 first filter means defining a first optical waveguide for directing all of said M first laser beams into a first optical path, wherein each of said M-1 first filter means transmits a corresponding one of said M first laser beams and reflects all other said M first laser beams;

fiber coupling means disposed adjacent to said first optical path for collecting said M first laser beams and for producing a respective one of said N output laser beams;

N optical fiber means receiving respective one of said N output laser beams for generating N received output beams; and

output means for recollimating and for focusing said N received output beams on a single spot,

where N and M are both integers ≧2.

15. The diode laser system as set forth in claim 14, wherein said output means comprises:

N collimating lenses for recollimating said N×M laser beams; and

a single transform lens focusing said recollimated N×M laser beams onto said single spot.

16. The diode laser system as set forth in claim 14, wherein said single spot corresponds to one end of a solid state laser.

17. The diode laser system as set forth in claim 14, wherein said single spot corresponds to one end of a rare-earth doped optical fiber.

18. The diode laser system as set forth in claim 14, wherein said single spot corresponds to one end of a dye laser.

19. The diode laser system as set forth in claim 14, wherein said generating means further comprises:

second means for generating M second laser beams, wherein each of said M second laser beams has a different single wavelength;

M-1 second filter means defining a second optical waveguide for directing all of said M second laser beams into a second optical path, wherein each of said M-1 second filter means transmits a corresponding one of said M second laser beams and reflects all other said M second laser beams;

rotating means for rotating the polarizations of said M second laser beams; and

polarization means disposed at the intersection of said first and second optical paths for coupling said M first

and M second laser beams into said second optical path to thereby produce 2M polarization coupled laser beams.

wherein said fiber coupling means collects said 2M polarization coupled laser beams to produce a respective one of said N laser beams.

20. The diode laser system as set forth in claim 19. wherein said fiber coupling device comprises a transform lens for receiving and for coupling said 2M polarization coupled laser beams to one of said N optical fiber means to thereby produce a respective one of said N output beams.

21. A method for generating a high energy laser beam. comprising:

(a) generating P collimated laser beams having an Mth wavelength;

(b) repeating step (a) M times so as to produce M×P collimated laser beams having M different wavelengths;

(c) coupling said M×P collimated laser beams into an optical path;

(d) coupling said M×P collimated laser beams into an ith optical fiber to thereby produce a corresponding ith output laser beam, where i=1 to N;

(e) repeating steps (a) through (d) N times to thereby generate N output laser beams;

(f) recollimating said N output laser beams to produce N recollimated laser beams; and

(g) focusing said N recollimated laser beams onto a single spot,

where M, N and P are integers ≧2.

22. The method as set forth in claim **21**, wherein step (c) comprises dichroically coupling said M×P collimated laser beams into said optical path.

23. The method as set forth in claim **21**, wherein step (c) comprises dichroically and polarization coupling said M×P collimated laser beams into said optical path.

24. The method as set forth in claim **21**, wherein step (c) comprises polarization coupling said M×P collimated laser beams into said optical path.

* * * * *

25. A diode laser system, comprising:

a laser head assembly generating an output beam, the laser head assembly including:

M modules which generate M laser beams, wherein each of said M laser beams has a different single wavelength; and

M-2 dichroic filters, wherein each of said M-2 dichroic filters transmits a corresponding one of said M laser beams and reflects all other of said M laser beams into a predetermined optical path to produce said output beam,

where M is an integer ≥2.

26. A diode laser system, comprising:

a laser head assembly which generates an output beam, the laser head assembly including:

M modules which generate M laser beams, wherein each of said M laser beams occupies a different wavelength band;

M-R dichroic filters, wherein each of said M-R dichroic filters transmits at least a respective one of said M laser beams occupying a given wavelength band and reflects all other of said M laser beams not occupying the given wavelength band; and

an optical device which combines said M laser beams to thereby produce said output beam,

wherein:

M and R are positive integers; and

M is an integer ≥2.

27. The diode laser system as recited in claim 26, wherein the optical device comprises means for collecting said M laser beams to thereby produce said output beam.

28. The diode laser system as recited in claim 26, wherein the optical device comprises a fiber coupling device which collects said M laser beams to thereby produce said output beam.

29. The diode laser system as recited in claim 26, wherein the optical device comprises a polarization combiner which combines first selected ones of said M laser beams with second selected ones of said M laser beams to thereby produce said output beam.

30. The diode laser system as recited in claim 29, wherein the first selected ones of said M laser beams are equal in number to the second selected ones of said M laser beams.

31. A laser head assembly which generates an output beam including M laser beams, comprising:

M modules generating M laser beams, wherein each of said M laser beams has a different single wavelength; and

M-2 dichroic filters, wherein each of said M-2 dichroic filters transmits a corresponding one of said M laser beams and reflects all other of said M laser beams;

wherein M is an integer ≥2.

32. The laser head assembly as recited in claim 31, further comprising a fiber coupling device collecting said M laser beams to produce an output beam;

33. A method for generating a high energy laser beam, comprising:

(a) generating P collimated laser beams having an Mth wavelength;

(b) repeating step (a) M times so as to produce MxP collimated laser beams having M different wavelengths; and

(c) coupling said MxP collimated laser beams into an optical path to produce a high energy laser beam,

wherein M and P are integers ≥2.

34. The method as recited in claim 33, wherein the step (c) comprises dichroically coupling said MxP collimated laser beams into said optical path.

35. The method as recited in claim 33, wherein the step (c) comprises dichroically and polarization coupling said MxP collimated laser beams into said optical path.

36. A diode laser system, comprising:

laser head assembly (LHA) which generates an output beam, the LHA including:

M modules generating M laser beams, wherein each of said M laser beams has a different single wavelength;

M-1 dichroic filters defining an optical waveguide for directing all of said M laser beams into the optical path, wherein each of said M-1 first dichroic filters transmits a corresponding one of said M laser beams and reflects all other said M laser beams; and

a fiber coupling device disposed adjacent to the optical path for collecting said M laser beams to thereby produce an output beam;

where M is an integer ≥ **2.**

37. A diode laser system, comprising:

laser head assembly (LHA) which generates an output beam, the LHA including:

M first modules generating M first laser beams, wherein each of said M first laser beams has a different single wavelength;

M-**1** first dichroic filters defining a first optical waveguide for directing all of said M first laser beams into a first optical path, wherein each of said M-**1** first dichroic filters transmits a corresponding one of said M first laser beams and reflects all other said M first laser beams;

M second modules generating M second laser beams, wherein each of said M second laser beams has a different single wavelength;

M-**1** second dichroic filters defining a second optical waveguide for directing all of said M second laser beams into a second optical path, wherein each of said M-**1** second dichroic filters transmits a corresponding one of said M second laser beams and reflects all other said M second laser beams;

a polarization combiner disposed at the intersection of said first and second optical paths

which coupling said M first and M second laser beams into the second optical path to thereby produce **2M** polarization coupled laser beams; and

a fiber coupling device disposed adjacent to said first and second optical paths for coupling said 2M polarization coupled laser beams to thereby produce the output beam,

where M is an integer ≥ 2.

38. A laser head assembly (LHA) which generates an output beam, comprising:

M modules generating M laser beams, wherein each of said M laser beams has a different single wavelength;

M-**R** dichroic filters defining a first optical waveguide for directing all of said M laser beams into a first optical path, wherein each of said M-**R** dichroic filters transmits at least one of said M laser beams;

S second modules generating S laser beams, wherein each of said S laser beams has a different single wavelength;

S-**T** dichroic filters defining a second optical waveguide for directing all of said S laser beams into a second optical path, wherein each of said S-T dichroic filters transmits at least one of said S laser beams;

a polarization combiner disposed at the intersection of said first and second optical paths which couple said M and said S laser beams into a common optical path to thereby produce M + S polarization coupled laser beams; and

a fiber coupling device disposed adjacent to said first and second optical paths for coupling said M + S polarization coupled laser beams to thereby produce the output beam,

wherein:

M, R, S and T are positive integers; and

at least one of M and S is ≥ 2.

39. A diode laser system, comprising:

means for generating M laser beams, each of said M laser beams having a different wavelength;

M-R filter means defining a first optical waveguide for directing all of said M first laser beams into an optical path, wherein each of said M-**R** filter means transmits at least one of said M first laser beams; and

fiber coupling means disposed adjacent to said optical path for collecting said M laser beams to thereby produce an output laser beam,

wherein M and R are both positive integers, and

wherein M $\geq$ **2.**

40. A diode laser system, comprising:

first means for generating M first laser beams, wherein each of said M first laser beams has a different single wavelength;

M-1 first filter means defining a first optical waveguide for directing all of said M first laser beams into an optical path, wherein each of said M-**1** filter means transmits a corresponding one of said M first laser beams and reflects all other said M first laser beams;

second means for generating M second laser beams, wherein each of said M second laser beams has a different single wavelength;

M-1 second filter means defining a second optical waveguide for directing all of said M second laser beams into a second optical path, wherein each of said M-1 second filter means transmits a corresponding one of said M second laser beams and reflects all other said M second laser beams;

polarization combining means disposed at the intersection of said first and second optical paths for coupling said M first and said M second laser beams into said second optical path to thereby produce 2M polarization coupled laser beams; and

fiber coupling means disposed adjacent to said second optical path for collecting said 2M polarization coupled laser beams to thereby produce an output laser beam,

wherein M is a integer ≥ 2.

41. A method for generating a high energy laser beam, comprising:

(a) generating P collimated laser beams having an Mth wavelength;

(b) repeating step (a) M times so as to produce M×P collimated laser beams having M different wavelengths;

(c) coupling said M×P collimated laser beams into an optical path; and

(d) coupling said M×P collimated laser beams into an ith optical fiber to thereby produce a corresponding ith output laser beam, where i=1 to N;

where M, N and P are positive integers and both M and P ≥ 2.

ABSTRACT

A direct diode laser system includes N laser head assemblies (LHAs) generating N output beams, N optical fibers receiving respective N output beams and generating N received output beams, and a torch head recollimating and focusing the N received output beams onto a single spot. Preferably, each of the laser head assemblies of the direct diode laser system includes M modules generating M laser beams, wherein each of the M laser beams has a corresponding single wavelength of light, M-1 dichroic filters, wherein each of the M-1 dichroic filter transmits a corresponding one of the M laser beams and reflects all other wavelengths, and a fiber coupling device collecting the M laser beams to produce a respective one of the N output beams. In an exemplary case, the M-1 dichroic filters function as band pass filters. A method of generating a high fluence, high power laser beam is also described.

FIG.1
PRIOR ART

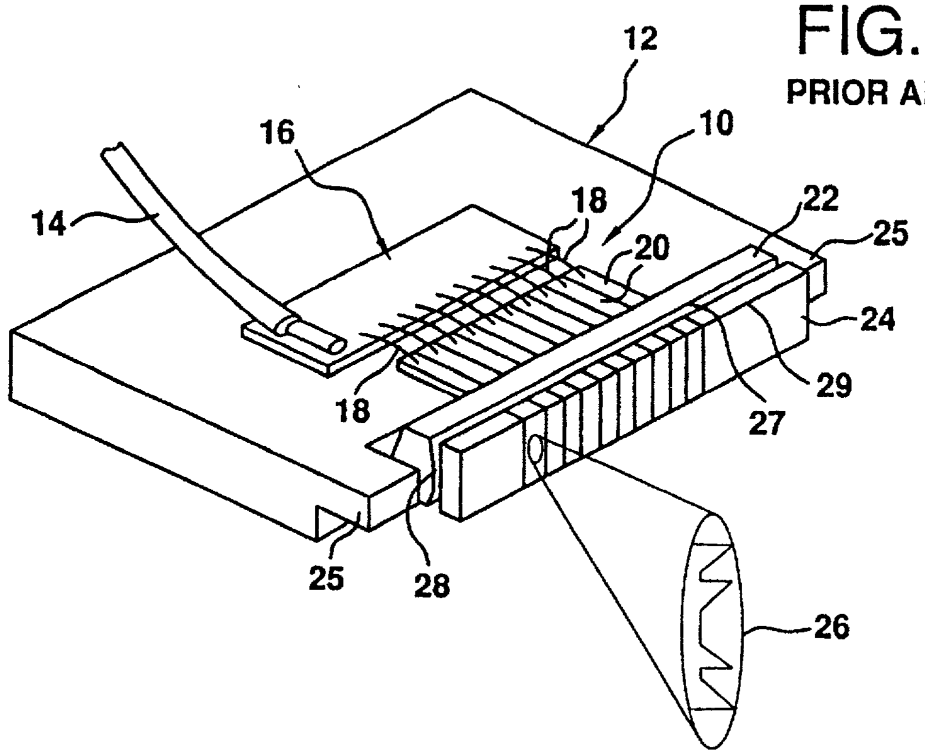


FIG.4
PRIOR ART

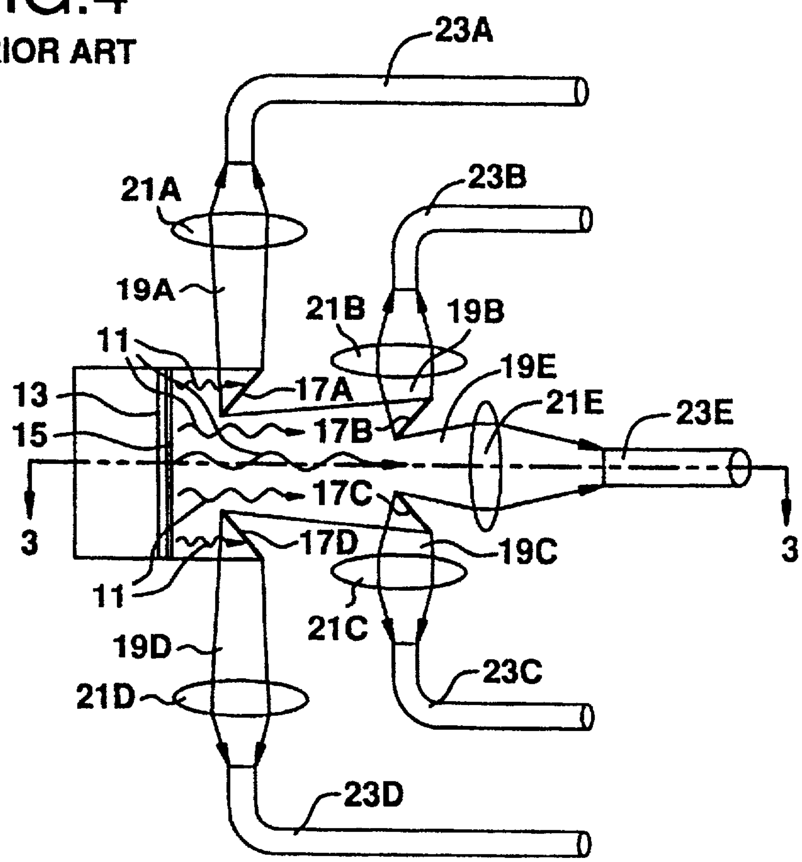


FIG.2
PRIOR ART

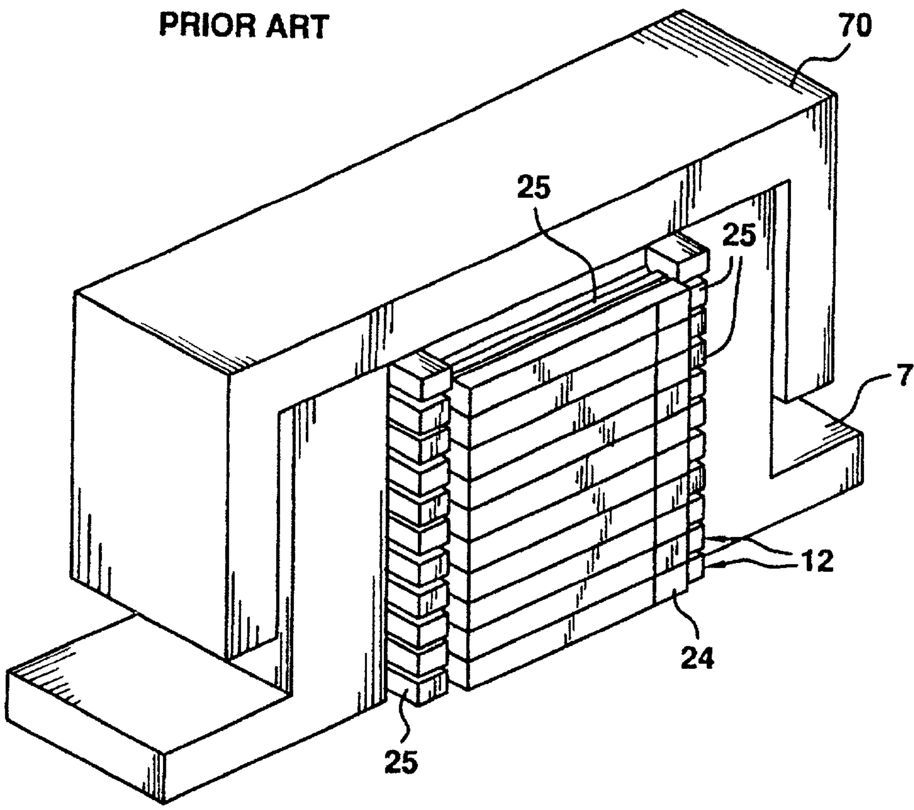
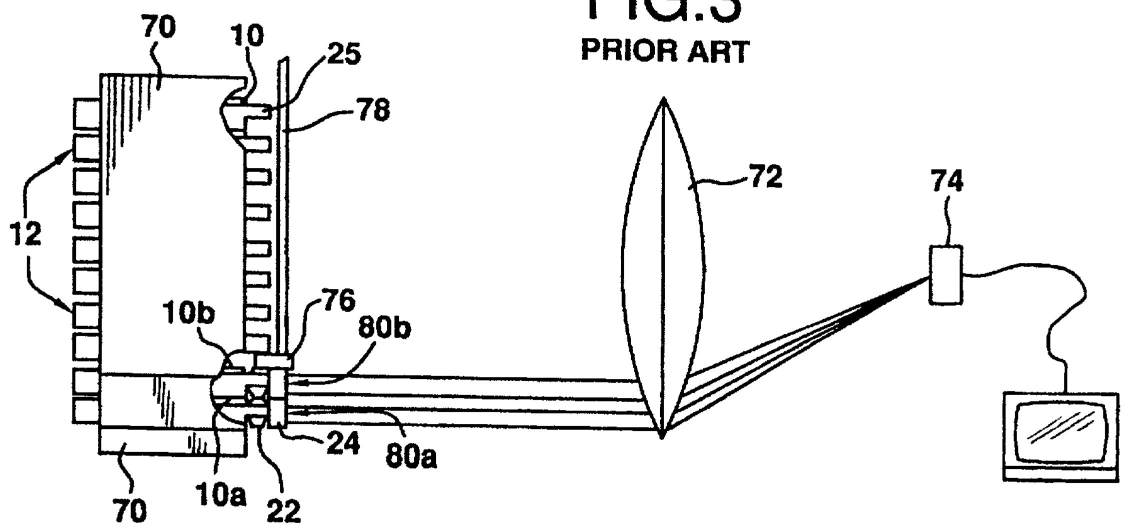


FIG.3
PRIOR ART



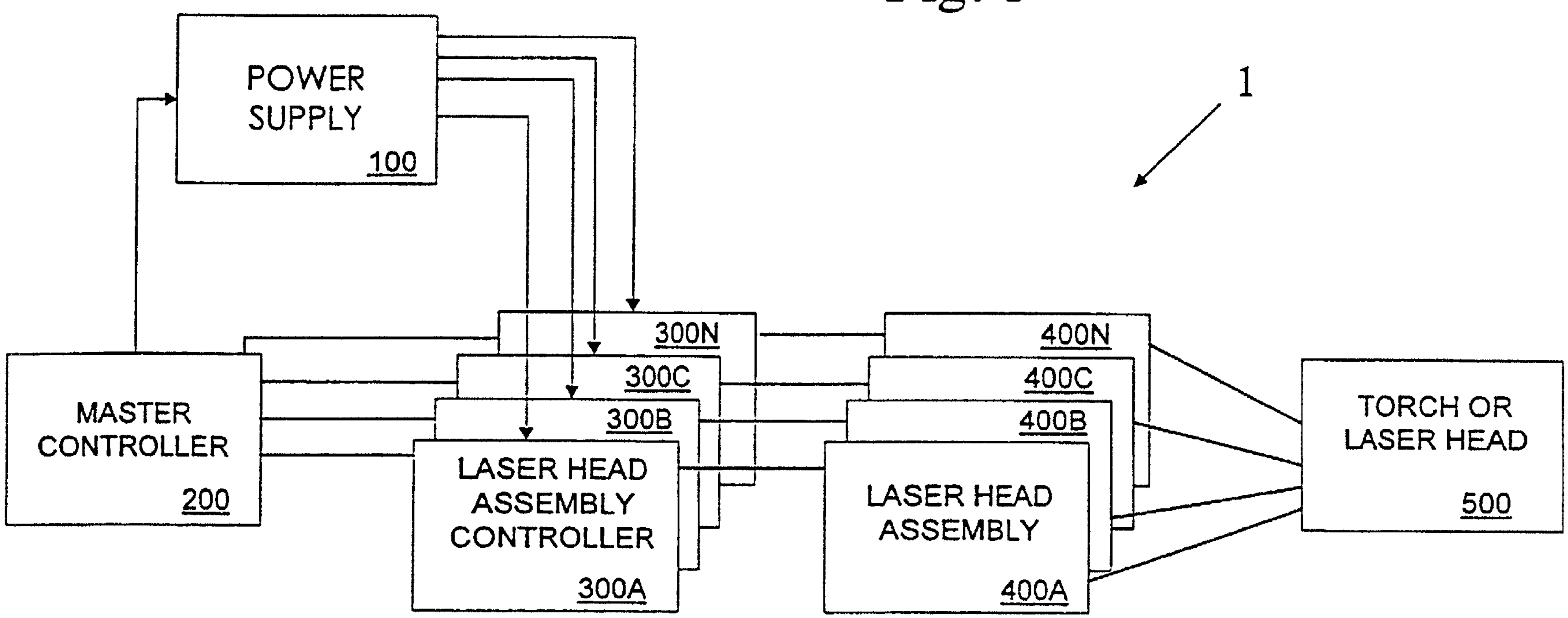
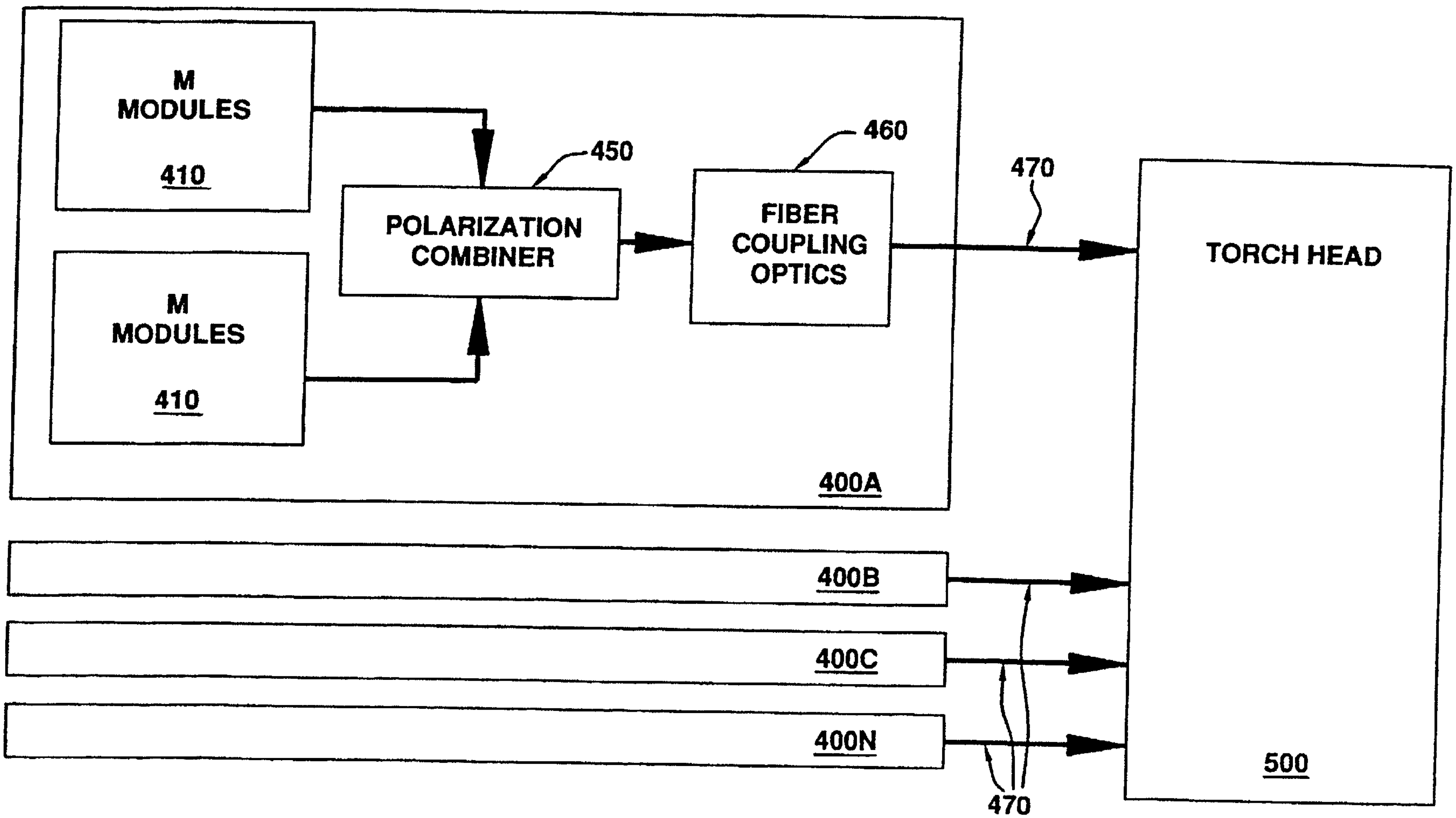
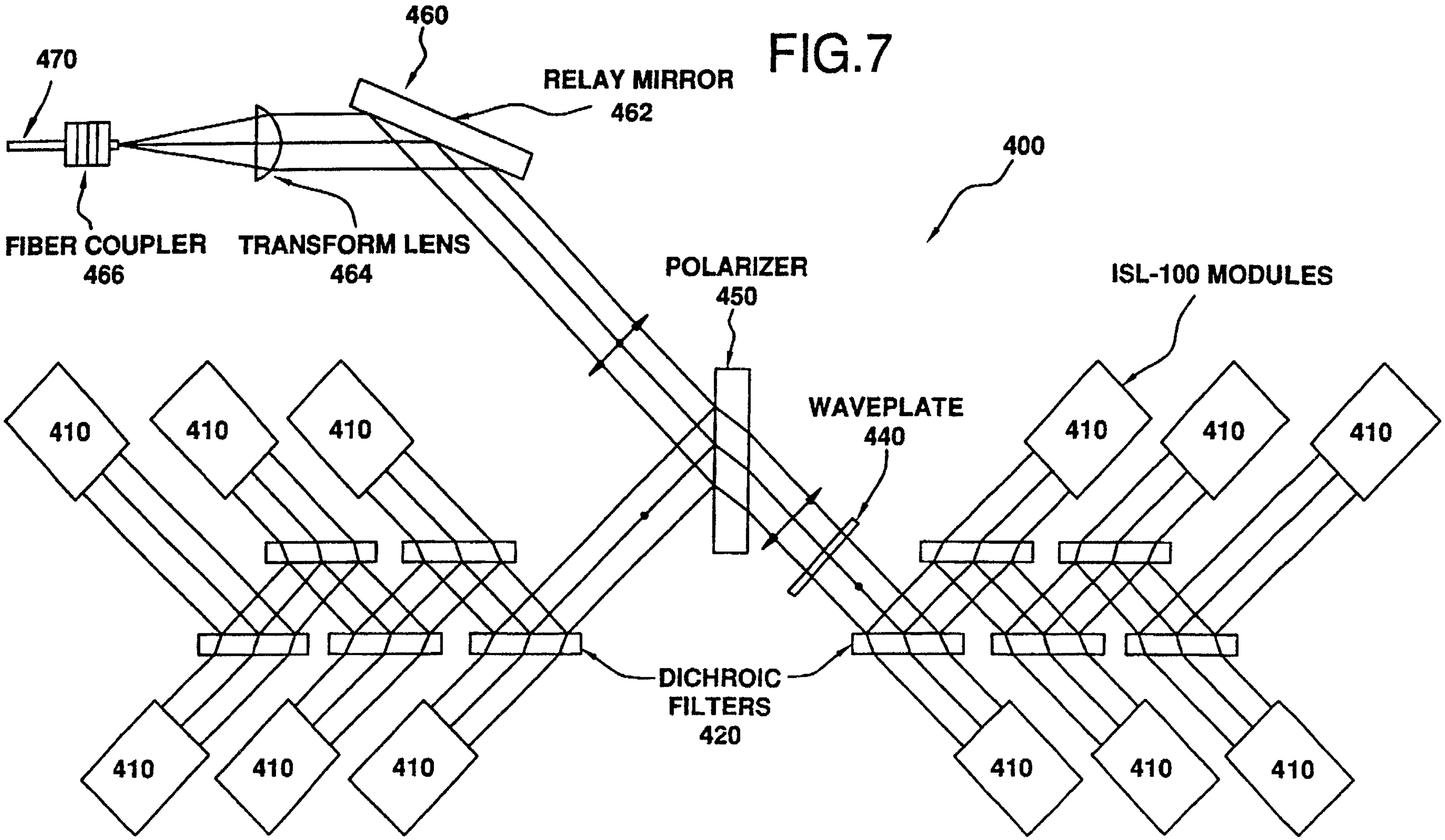

POWER SUPPLY
100
MASTER CONTROLLER
200
300N
300C
300B
LASER HEAD ASSEMBLY CONTROLLER
300A
400N
400C
400B
LASER HEAD ASSEMBLY
400A
TORCH OR LASER HEAD
500
1

Fig. 5

FIG.6


M
MODULES
410
M
MODULES
410
POLARIZATION
COMBINER
450
FIBER
COUPLING
OPTICS
460
470
400A
400B
400C
400N
470
TORCH HEAD
500



470
460
RELAY MIRROR
462
400
FIBER COUPLER
466
TRANSFORM LENS
464
POLARIZER
450
ISL-100 MODULES
WAVEPLATE
440
410
DICHROIC
FILTERS
420

FIG.7

FIG.8

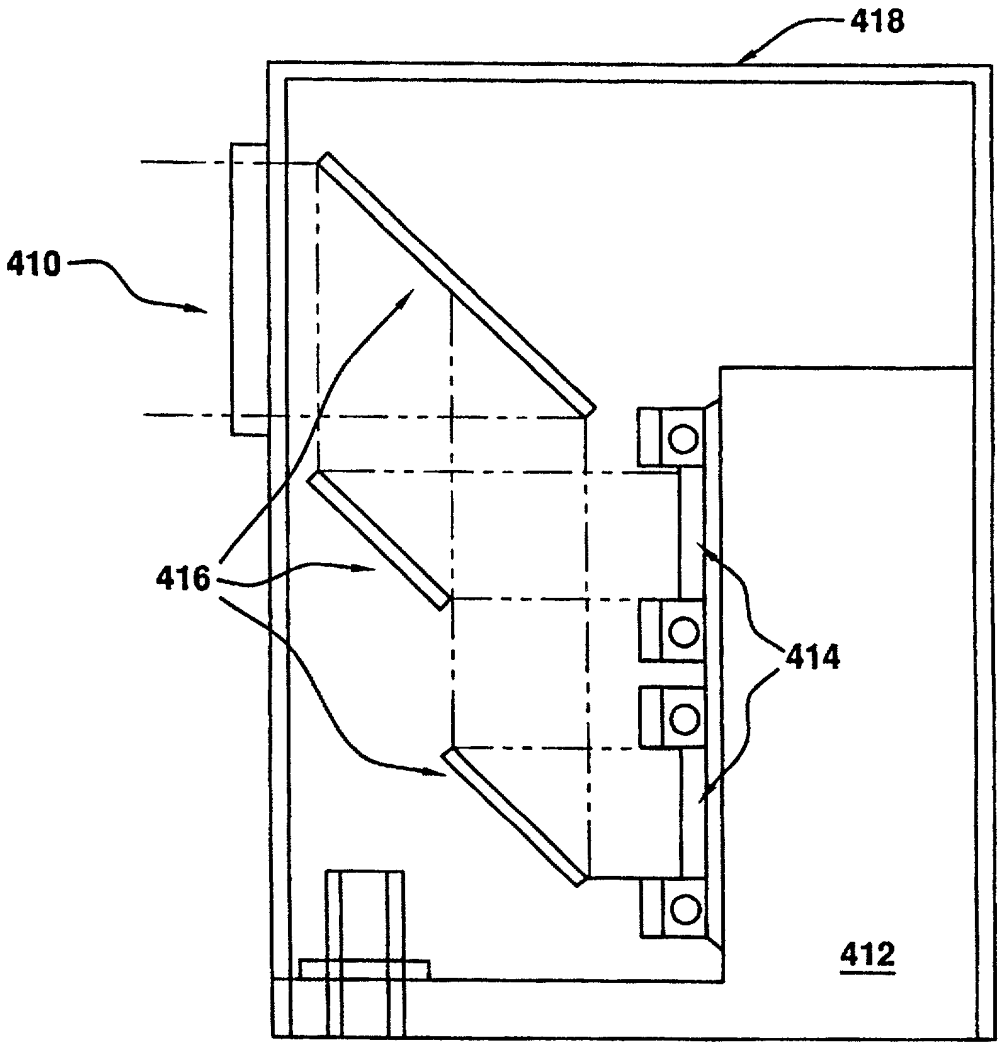
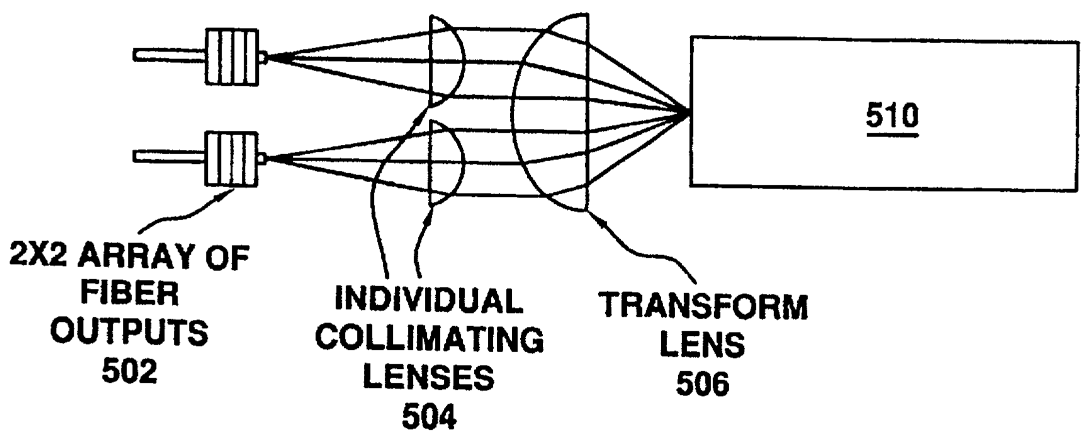


FIG.9


510
2X2 ARRAY OF FIBER OUTPUTS 502
INDIVIDUAL COLLIMATING LENSES 504
TRANSFORM LENS 506

REISSUE APPLICATION DECLARATION BY THE INVENTOR	Docket Number (Optional) D-3953-RE

As a below named inventor, I hereby declare that:
My residence, mailing address and citizenship are stated below next to my name.
I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is described and claimed in patent number **5,715,270**, granted **02/03/1998**, and for which a reissue patent is sought on the invention entitled **HIGH EFFICIENCY, HIGH POWER DIRECT DIODE LASER SYSTEMS AND METHODS THEREFOR**, the specification of which

☐ is attached hereto.

☒ was filed on **02/03/2000** as reissue application number **09/ 498,254** and was amended on **N/A**.
(If applicable)

I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.
I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.
I verily believe the original patent to be wholly or partly inoperative or invalid, for the reasons described below. (Check all boxes that apply.)

☐ by reason of a defective specification or drawing.

☒ by reason of the patentee claiming more or less than he had the right to claim in the patent.

☐ by reason of other errors.

At least one error upon which reissue is based is described below. If the reissue is a broadening reissue, such must be stated with an explanation as to the nature of the broadening:

In U.S. Patent No. 5,715,270, Applicants erroneously, and without deceptive intent, claimed less than they were entitled to claim. For example, claim 1 of the '270 patent recited:

1. A diode laser system, comprising:
N laser head assemblies (LHAs) generating N output beams, wherein each of said N LHAs includes:
M modules generating M laser beams, wherein each of said M laser beams has a different single wavelength;
M-2 dichroic filters, wherein each of said M-2 dichroic filters transmits a corresponding one of said M laser beams and reflects all other of said M laser beams;

REISSUE APPLICATION DECLARATION BY THE INVENTOR	Docket Number (Optional) D-3953-RE

a fiber coupling device collecting said M laser beams to produce a respective one of said N output beams;

N optical fibers receiving respective ones of said N output beams and generating N received output beams; and

an optical assembly recollimating and focusing said N received output beams on a single spot,

where N and M are both integers ≥ 2.

In doing so, Applicants erroneously claimed a diode laser system including at least two laser head assemblies. However, the laser diode system to which the Applicants believe they are entitled is as recited below:

25. A diode laser system, comprising:

a laser head assembly generating an output beam, wherein the laser head assembly includes:

M modules which generates M laser beams, and wherein each of said M laser beams has a different wavelength band; and

M-2 dichroic filters, wherein each of said M-2 dichroic filters transmits a corresponding one of said M laser beams and reflects all other of said M laser beams into a predetermined optical path to produce said output beam; and

where M is an integer ≥2.

It will be appreciated from a comparison of claims 1 of the '270 patent and claim 25 of the Reissue application, the recitation of but a single laser head assembly permits additional elements, such as the N optical fibers of claim 1 to be omitted from the claimed diode laser system.

(REISSUE APPLICATION DECLARATION BY THE INVENTOR, *page 2*)	Docket Number (Optional) **D-3953-RE**

All errors corrected in this reissue application arose without any deceptive intention on the part of the applicant. As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the United States Patent and Trademark Office connected therewith.

Name(s)	Registration Number
Raymond H. J. Powell, Jr.	34,231
Robert A. Westerlund	31,439
Ramon R. Hoch	34,108

OIPE
DEC 29 2000
PATENT & TRADEMARK OFFICE

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine and imprisonment, or both, under 18 U.S.C. 1001, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this declaration is directed.

Full name of sole or first inventor (given name, family name)
Mark S. Zediker

Inventor's signature	Date
Residence **Same as Mailing Address**	Citizenship **United States**

Mailing Address **4005 Waneway Court, Florissant, MO 63034-3218**

Full name of second joint inventor (given name, family name)
Robert R. Rice

Inventor's signature Robert R Rice	Date 18 December 2000
Residence **Same as Mailing Address**	Citizenship **United States**

Mailing Address **14736 Greenleaf Valley Drive, Chesterfield MO, 63017**

Full name of third joint inventor (given name, family name)
John M. Haake

Inventor's signature	Date
Residence **Same as Mailing Address**	Citizenship **United States**

Mailing Address **5 Gum Tree Place, St. Charles, MO, 63301-1296**

☐ *Additional joint inventors are named on separately numbered sheets attached hereto.*

REISSUE APPLICATION DECLARATION BY THE INVENTOR	Docket Number (Optional) D-6953-RE

As a below named inventor, I hereby declare that:
My residence, mailing address and citizenship are stated below next to my name.
I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is described and claimed in patent number 5,715,270, granted 02/03/1998, and for which a reissue patent is sought on the invention entitled **HIGH EFFICIENCY, HIGH POWER DIRECT DIODE LASER SYSTEMS AND METHODS THEREFOR**, the specification of which

☐ is attached hereto.

☒ was filed on 02/03/2000 as reissue application number 09/ 498,254 and was amended on N/A.
(If applicable)

I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.
I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.
I verily believe the original patent to be wholly or partly inoperative or invalid, for the reasons described below. (Check all boxes that apply.)

☐ by reason of a defective specification or drawing.

☒ by reason of the patentee claiming more or less than he had the right to claim in the patent.

☐ by reason of other errors.

At least one error upon which reissue is based is described below. If the reissue is a broadening reissue, such must be stated with an explanation as to the nature of the broadening:

In U.S. Patent No. 5,715,270, Applicants erroneously, and without deceptive intent, claimed less than they were entitled to claim. For example, claim 1 of the '270 patent recited:

1. A diode laser system, comprising:
N laser head assemblies (LHAs) generating N output beams, wherein each of said N LHAs includes:
M modules generating M laser beams, wherein each of said M laser beams has a different single wavelength;
M-2 dichroic filters, wherein each of said M-2 dichroic filters transmits a corresponding one of said M laser beams and reflects all other of said M laser beams;

(REISSUE APPLICATION DECLARATION BY THE INVENTOR, page 2)

Docket Number (Optional)
D-3953-RE

All errors corrected in this reissue application arose without any deceptive intention on the part of the applicant. As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the United States Patent and Trademark Office connected therewith.

Name(s)	Registration Number
Raymond H. J. Powell, Jr.	34,231
Robert A. Westerlund	31,439
Ramon R. Hoch	34,108

Correspondence Address: Direct all communications about the application to:

☐ Customer Number [ ] → Place Customer Number Bar Code Label here

Type Customer Number here

☒ Firm or Individual Name	WESTERLUND POWELL, P.C.				
Address	122 N. Alfred Street				
Address					
City	Alexandria	State	VA	Zip	22314-3011
Country	United States				
Telephone	(703) 706-5862	Fax	(703) 706-5860		

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine and imprisonment, or both, under 18 U.S.C. 1001, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this declaration is directed.

Full name of sole or first inventor (given name, family name)
Mark S. Zediker

Inventor's signature	[signature]	Date	12/20/00
Residence	Same as Mailing Address	Citizenship	United States
Mailing Address	315 Merlin Drive, St. Charles, MO 63304		

Full name of second joint inventor (given name, family name)
Robert R. Rice

Inventor's signature		Date	
Residence	Same as Mailing Address	Citizenship	United States
Mailing Address	14736 Greenleaf Valley Drive, Chesterfield MO, 63017		

Full name of third joint inventor (given name, family name)
John M. Haake

Inventor's signature	[signature]	Date	12/20/00
Residence	Same as Mailing Address	Citizenship	United States
Mailing Address	5 Gum Tree Place, St. Charles, MO, 63301-1296		

☐ Additional joint inventors are named on separately numbered sheets attached hereto.

PTO/SB/51 (10-00)
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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

REISSUE APPLICATION DECLARATION BY THE INVENTOR	Docket Number (Optional) **D-3953-RE**

a fiber coupling device collecting said M laser beams to produce a respective one of said N output beams;

N optical fibers receiving respective ones of said N output beams and generating N received output beams; and

an optical assembly recollimating and focusing said N received output beams on a single spot,

where N and M are both integers ≥ 2.

In doing so, Applicants erroneously claimed a diode laser system including at least two laser head assemblies. However, the laser diode system to which the Applicants believe they are entitled is as recited below:

25. A diode laser system, comprising:

a laser head assembly generating an output beam, wherein the laser head assembly includes:

M modules which generates M laser beams, and wherein each of said M laser beams has a different wavelength band; and

M-2 dichroic filters, wherein each of said M-2 dichroic filters transmits a corresponding one of said M laser beams and reflects all other of said M laser beams into a predetermined optical path to produce said output beam; and

where M is an integer ≥2.

It will be appreciated from a comparison of claims 1 of the '270 patent and claim 25 of the Reissue application, the recitation of but a single laser head assembly permits additional elements, such as the N optical fibers of claim 1 to be omitted from the claimed diode laser system.

REISSUE APPLICATION DECLARATION BY THE ASSIGNEE

Docket Number (optional)
D-3953-RE

OIPE JC139 DEC 29 2000 PATENT & TRADEMARK OFFICE

I hereby declare that:

My residence and mailing address and citizenship are stated below next to my name.

I am authorized to act on behalf of the following assignee: **McDonnell Douglas Corporation**

and the title of my position with said assignee is: **Chief Counsel**

The entire title to the patent identified below is vested in said assignee.

Name of Patentee(s)

Mark S. Zediker, Robert R. Rice, and John M. Haake

Patent Number	Date of Patent Issued
5,715,270	**02/03/1998**

Title of Invention

High Efficiency, High Power Direct Doide Laser Systems and Methods Therefor

I believe said patentee(s) to be the original, first and sole/joint inventor(s) of the subject matter which is described and claimed in said patent, for which a reissue patent is sought on the invention entitled **High Efficiency, High Power Direct Doide Laser Systems and Methods Therefor**,

the specification of which

☐ is attached hereto.

☒ was filed on **02/03/2000** as reissue application number **09 /498,254**
and was amended on **N/A**
(If applicable)

I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.

I verily believe the original patent to be wholly or partly inoperative or invalid, for the reasons described below. (Check all boxes that apply.)

☐ by reason of a defective specification or drawing.

☒ by reason of the patentee claiming more or less than he had the right to claim in the patent.

☐ by reason of other errors.

At least one error upon which reissue is based is described as follows:

See Attached Sheet

[Attach additional sheets, if needed.]

All errors corrected in this reissue application arose without any deceptive intention on the part of the applicant

REISSUE APPLICATION DECLARATION BY THE ASSIGNEE	Docket Number (optional) D-3953-RE

In U.S. Patent No. 5,715,270, Applicants erroneously, and without deceptive intent, claimed less than they were entitled to claim. For example, claim 1 of the '270 patent recited:

1. A diode laser system, comprising:
N laser head assemblies (LHAs) generating N output beams, wherein each of said LHAs includes:
M modules generating M laser beams, wherein each of said M laser beams has a different single wavelength;
M-2 dichroic filters, wherein each of said M-2 dichroic filters transmits a corresponding one of said M laser beams and reflects all other of said M laser beams;
a fiber coupling device collecting said M laser beams to produce a respective one of said N output beams;
N optical fibers receiving respective ones of said N output beams and generating N received output beams; and
an optical assembly recollimating and focusing said N received output beams on a single spot,
where N and M are both integers ≥ 2.

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a laser head assembly generating an output beam, wherein the laser head assembly includes:
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where M is an integer ≥ 2.

It will be appreciated from a comparison of claims 1 of the '270 patent and claim 25 of the Reissue application, the recitation of but a single laser head assembly permits additional elements, such as the N optical fibers of claim 1 to be omitted from the claimed diode laser system.

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REISSUE APPLICATION DECLARATION BY THE ASSIGNEE	Docket Number (Optional) D-3953-DE

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the United States Patent and Trademark Office connected therewith.

Name(s)	Registration Number
Raymond H. J. Powell, Jr.	34,231
Robert A. Westerlund	31,439
Ramon R. Hoch	34,108

Correspondence Address: Direct all communications about the application to:

☐ Customer Number [ ] Type Customer Number Here → Place Customer Number Bar Code Label Here

OR

[X] Firm or Individual Name	WESTERLUND POWELL, P.C.
Address	122 N. Alfred Street
Address	
City	Alexandria State VA Zip 22314-3011
Country	United States
Telephone	(703) 706-5862 Fax (703) 706-5860

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine and imprisonment, or both, under 18 U.S.C. 1001, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this declaration is directed.

Full name of person signing (given name, family name)
Richard J. Wickham, Chief Counsel

Signature Richard J. Wickham Date 12/20/2000

Address of Assignee
P O Box 516, St. Louis, MO, 63166-0516

Patentee	Citizenship
Mark S. Zediker	United States

Residence/Mailing Address
315 Merlin Drive, St. Charles MO 63304

Patentee	Citizenship
Robert R. Rice	United States

Residence/Mailing Address
14736 Greenleaf Valley Drive, Chesterfield, MO, 63017

[X] Additional Patentees are named on separately numbered sheets attached hereto.

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U.S Patent and Trademark Office; U S. DEPARTMENT OF COMMERCE

List of Additional Patentees

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number

REISSUE APPLICATION DECLARATION BY THE ASSIGNEE	Docket Number (Optional) D-3953-RE
Patentee **John M. Haake**	Citizenship **United States**
Residence/Mailing Address **5 Gum Tree Place, St. Charles, MO, 63301-1296**	
Patentee	Citizenship
Residence/Mailing Address	
Patentee	Citizenship
Residence/Mailing Address	
Patentee	Citizenship
Residence/Mailing Address	
Patentee	Citizenship
Residence/Mailing Address	
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Patentee	Citizenship
Residence/Mailing Address	
Patentee	Citizenship
Residence/Mailing Address	
☐ Additional Patentees are named on separately numbered sheets attached hereto.	

(Sheet 1 of 1)

PTO/SB/96 (08-00)
Approved for use through 10/31/2002 OMB 0651-0031
U.S.Patent and Trademark Office; U.S DEPARTMENT OF COMMERCE

STATEMENT UNDER 37 CFR 3.73(b)

Applicant/Patent Owner: McDonnell Douglas Corporation

Application No./Patent No.: 5,715,270 Filed/Issue Date: February 3, 1998

Entitled: High Efficiency, High Power Direct Diode Laser Systems and Methods Therefor

McDonnell Douglas Corporation, a P O Box 516, St. Louism MO, 63166-0516,
(Name of Assignee) (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

OIPE JC199 DEC 29 2000 PATENT & TRADEMARK OFFICE

states that it is:

1. [X] the assignee of the entire right, title, and interest; or
2. [ ] an assignee of less than the entire right, title and interest.
The extent (by, percentage) of its ownership interest is ________%

in the patent application/patent identified above by virtue of either:

A. [X] An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel 8368, Frame 0083, or for which a copy thereof is attached.

OR

B. [ ] A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as shown below:

1. From:______________ To:______________
The document was recorded in the United States Patent and Trademark Office at Reel ________, Frame ________, or for which a copy thereof is attached.
2. From:______________ To:______________
The document was recorded in the United States Patent and Trademark Office at Reel ________, Frame ________, or for which a copy thereof is attached.
3. From:______________ To:______________
The document was recorded in the United States Patent and Trademark Office at Reel ________, Frame ________, or for which a copy thereof is attached.

[ ] Additional documents in the chain of title are listed on a supplemental sheet.

[ ] Copies of assignments or other documents in the chain of title are attached.
[NOTE: A separate copy (*i.e.,* the original assignment document or a true copy of the original document) must be submitted to Assignment Division in accordance with 37 CFR Part 3, if the assignment is to be recorded in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

12/20/2000
Date

Richard J. Wickham
Typed or printed name

Richard J. Wickham
Signature

Chief Counsel
Title

Burden Hour Statement: This form is estimated to take 0.2 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, Washington, DC 20231 DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS SEND TO Assistant Commissioner for Patents, Washington, DC 20231